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DENTAL X-RAY AUTOPROCESSORS: TECHNICAL AND OPERATIONAL EVALUATION

Joe B. Drane III, Lieutenant Colonel, USAF, DC
Robert A. Barnes, Master Sergeant, USAF
David W. Sexson, Master Sergeant, USAF
Paul R. Park, Colonel, USAF, DC

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USAF SCHOOL OF AEROSPACE MEDICINE
Human Systems Division (AFSC)
Brooks Air Force Base, TX 78235-5301

NOTICES

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The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

JOE B. DRANE III, Lt Col, USAF, DC
Project Scientist

PAUL R. PARK, Colonel, USAF, DC
Supervisor

JEFFREY G. DAVIS, Colonel, USAF, MC
Commander

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The purpose of this study by the USAF Dental Investigation Service (USAFSAM/NGD) was to evaluate nine commercial dental x-ray automatic film processors. Three USAFSAM evaluators compared the film processors against locally developed criteria. This report stresses radiographic quality control. Precision equipment--an X-Rite Model 303 sensitometer, an X-Rite Model 301 densitometer, and an aluminum stepwedge--was used to make precise, repeatable exposures on x-ray film. The densitometer was used to measure optical densities of processed x-ray film. USAF base dental surgeons should be able to make decisions on which film processors to purchase based on the findings of this report. Keywords

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Joe B. Drane III, Lt Col, USAF, DC

22b. TELEPHONE (Include Area Code)
(512) 536-3502

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

DENTAL X-RAY AUTOPROCESSORS: TECHNICAL AND OPERATIONAL EVALUATION

INTRODUCTION

The evolution from developing tray to developing tanks to processing machine to automatic processing machine was a blessing for the dental technician. It kept his hands out of messy chemicals. Daylight developing tanks kept him out of the darkroom for extended periods. Processing machines speeded up the process and automatic replenishment introduced accuracy not previously possible because dental x-ray labs tended to underreplenish (I forgot) or to overreplenish (Did I replenish, or didn't I?).

The small dental clinic in the field with an x-ray lab in a closet doesn't want to be concerned with quality control research. It just wants readable x rays. To make it possible for the small lab to have this degree of freedom requires some extensive quality control research by the manufacturer and by the USAF Dental Investigation Service.

The USAF Dental Investigation Service (DIS) regularly receives requests for dental x-ray autoprocessor information. The requests have come at a time of rapid manufacturer turnover in the autoprocessor market. This project was initiated to compare available dental x-ray processors, and to determine their suitability for U.S. Air Force (USAF) use. The longevity of these units was not measured.

BACKGROUND

One of the most important points illuminated by a review of the literature, with respect to high quality radiographs, is that regardless of the autoprocessor used, regular and frequent maintenance is absolutely essential. Meticulous processing techniques are critical to the production of high quality radiographs (1). Detailed instructions for exacting procedures are too often overlooked or not understood by the operator. About 80-90% of poor film quality is caused by improperly cleaned processors and improper solution management (2). In automatic processing, a close coordination of clean transport mechanisms, proper processing chemicals, controlled temperatures, and high quality film is essential to achieve a high quality end product (3). With this requirement in mind, investigators at DIS compared six automatic x-ray film processors.

The literature reveals several autoprocessor comparison studies, but only one conducted recently, and only one in which film quality was compared among machines. In 1981, Wuermann and Manson-Hing published a comparison chart of six autoprocessors (4). They based their comparisons on data provided by manufacturers and sales representatives. Some of the processors they reviewed are no longer available. In 1984, Stockman, Foster, and Young of the USAF

DIS conducted a comparison study of seven processors (5). Although the study compared physical features of the autoprocessors, it did not compare image quality differences in x-ray films developed in the machines. Two of the seven autoprocessors from that study are no longer available. Two others are available under a different brand name, having been changed and "improved" according to the manufacturer.

In 1980, Thunthy compared film quality differences in five automatic processors (6). He used manually processed films as the standard. Differences in fog production were visually undetectable and clinically unimportant. He noted significant differences in image contrast in high-density regions as produced by the various processors, but little difference in low-density regions. He noted no resolution differences within film types and did not compare image quality at high "endo" processing speeds. The "endo" developing speed is a fast roller speed in dental x-ray processors providing quick development of x-rays used to verify root length in endodontics. In 1987, Clinical Research Associates (CRA) compared the physical properties of four autoprocessors (7). They rated the units based on twenty features they felt were important when purchasing an autoprocessor. It should be noted that CRA's report does not discuss materials or methods of data collection. It is not known how they obtained their data.

MATERIALS AND METHODS

Following solicitation by the DIS, five dental equipment manufacturers provided a total of nine models of x-ray autoprocessors for evaluation (Table 1). Investigators divided the testing protocol into three data collection and evaluation phases, two of which were objective and one subjective. Data concerning the first two phases was collected on an autoprocessor worksheet (Table 2).

In Phase I, investigators collected and recorded objective physical characteristics data using the autoprocessor worksheet and tabulated their results (Table 3). The English system for measurements was used. Manufacturers were contacted for clarification only when evaluators could not obtain answers for this phase through direct observation or through product literature. The decision on which items of information to collect in this phase was based on a previous study (5), and on the evaluators' field experiences and resultant knowledge of the needs of users in the clinical setting.

In Phase II, investigators collected subjective impressions from three observers concerning the machines' physical features. All machines were in a single room at the same time and were available for review as dry specimens; that is, they were assembled but not attached to utilities. Each observer viewed and evaluated the machines independently and at a separate time from other raters. Observers rated each item of each machine on a scale of one (poor) to five (excellent) and recorded their impressions using the autoprocessor work sheet (Table 2). They did not discuss their findings prior to submission of their reports.

The observer team consisted of a medical equipment repairman from the USAF School of Aerospace Medicine (SAM), Maintenance and Management Section, and two dental technicians from DIS. Investigators made no attempt to randomize the order in which observers viewed the autoprocessors for evaluation. Nor was any attempt made to calibrate the examiners beyond the expected expertise of their positions as medical equipment repair personnel and as dental technicians. The raters' results were collected (Table 4) and totals averaged (Table 5). Findings were then statistically evaluated to check the results in Table 5.

Evaluators statistically compared the observers' subjective findings in three stages. They first measured the ranges each observer used in scoring the processors' features (Table 7). Next, investigators developed coefficients of correlation among the observers (Table 8). In this stage, the findings of each observer were compared to the findings of every other observer. Using Spearman's Rho, investigators determined the interevaluator concordance or correlation. The higher the correlation coefficient (in the presence of a wide range of values) the more valid the findings. The final stage in the statistical evaluation was the ranking of the autoprocessors by observer and by machine feature (Table 9). Agreement among observers as to which machines were best (in the presence of good concordance and good range) helped investigators make final purchasing recommendations.

Phase III, the final data collection and evaluation phase, objectively measured and rated as acceptable or unacceptable the quality of the product produced by each autoprocessor. Investigators measured the densities of developed radiographs from each machine and ultimately translated these density findings to quality.

Radiography is a photographic process. Therefore, photographic terms are used to describe the science, and photographic materials and methods are used in its application. The terms used in this report may not be familiar with all readers in the field; therefore, a few definitions may be in order before proceeding.

Illuminance is the light (luminous flux) falling (incident) on a sample (developed film in this case).

Transmittance (expressed as a decimal fraction or percentage) is the ratio of transmitted to available illuminance. If an incident illuminance of 75 meter candles (mc) falls on our sample and 25 mc of that incident illuminance is transmitted, the transmittance is 0.33 or 33%.

Opacity is the reciprocal of transmittance. For a transmittance of 33%, the opacity is 3.0.

Density is the logarithm (to the base 10) of opacity. Here the density is 0.48.

The effect of our sample on light can be measured in any of the three terms described above. However, the accepted standard used to measure the light stopping ability of a medium is density. The visual process is approximately logarithmic - therefore, density approximates a measure of what the eye sees.

Compare the effect of light on four thicknesses of a medium. (Each thickness has, in this case, a transmittance of 0.20.)

Thickness	Transmittance	Opacity	Density
1	0.20	5.0	0.70
2	0.040	25.0	1.40
3	0.0080	125.0	2.10
4	0.0016	625.0	2.80

Transmittance and opacity vary exponentially as can be seen in the table above (8). However, density is proportional to the sample's thickness. The density of four layers is four times the density of one layer. Visualize the four layers from the table side by side and you have a step wedge.

Photographic sensitometry is the science of measuring the effect of radiation on sensitized emulsions (silver). In the case of radiographs the radiation is invisible. Exposure (the product of radiation times time) of the silver is proportional to the amount of radiation falling on the subject.

A photographic sensitometer uses a precision, calibrated light source to expose photographic materials. Variability between exposures using a sensitometer is extremely small. It can, therefore, be used as a source of reproducible exposures for radiographic film. In this test investigators used the X-Rite Model 303 sensitometer.

By exposing film through calibrated step wedges, we place known exposures on the film. After these films are developed in processing machines or developing tanks, we can measure the resulting densities on a densitometer. Variations in density from our standard will point out variations in developer concentrations, solution temperature, and machine speed or variations in film speed caused by age or improper storage conditions (exposure to heat, radiation, or high humidity).

The radiographs in this study were exposed under identical conditions and were developed in each machine under ideal conditions as set forth by the manufacturers in their operating instructions. Significant variables were limited to machine developing speed and the time of day that processing occurred.

To measure and compare image density, evaluators first created a processed film density standard. Using Kodak D-58 Intraoral Film and DF-75 Extraoral Film, they took radiographic images of an aluminum stepwedge (using the GE 1000 x-ray machine) and of an optical stepwedge (using the X-Rite Model 301 sensitometer) respectively.

In 1985, Manson-Hing and Bloxom reported using the aluminum stepwedge as a quality control device for monitoring processing solutions (9). Based upon their validation of the stepwedge as a comparison device, DIS evaluators used it to expose all intraoral films; they compared step densities between the machine-developed and the hand-developed radiographs. Members of the Fabrication Branch of the Technical Services Division, USAF School of

Aerospace Medicine, machined the aluminum stepwedge from commercially pure #1100 aluminum with base measurements of 10 x 30 mm. The stepwedge contains a total of eight steps, each 10 x 4 mm; the steps are 2, 4, 6, 8, 10, 12, 14, and 16 mm thick. The result is a device resembling a small staircase, which when radiographed, projects eight shadows of varying densities on the x-ray film. Investigators used this stepwedge as a test object when exposing the intraoral film. They exposed all intraoral radiographs at 70kVp and 10mA for 1 s using the General Electric 1000 Intraoral X-Ray Machine. They exposed all extraoral radiographs using the X-Rite #303 Sensitometer at the blue film setting for the standard machine default period of time.

The extraoral (panoramic) film required a different method for creating a film density standard due to the need for an intensifying screen when exposing extraoral film. Investigators used an optical stepwedge to shadow the film. The optical stepwedge is similar to a developed x-ray image of an aluminum stepwedge. Investigators used it in the X-Rite Model 303 sensitometer, a device used in this study to simulate exposure of extraoral film in a panoramic x-ray cassette. The principle of the sensitometer was discussed previously.

Kodak processing solutions were used to develop the radiographs. Evaluators used RP X-omat chemistry in the autoprocessors and GBX developer for manual processing.

The image densities of the products of each machine were measured at standard speed and, where possible, at the fastest "endo" developing speed, and at an intermediate speed. The intermediate speeds chosen were as close as possible to a speed midway between the machines' fastest and standard speeds (Figures 8-13). Since the number of machine speeds varies widely (range is from one speed in five of the machines to 11 speeds in the Air Techniques AT 2000 [Table 3]), the investigators measured no more than three settings on any one processor.

Each machine's ability to maintain the image density of its processed x-ray films was tested throughout an 8-h workday. Image density data was collected by processing sets of test films through the machines at each of the tested, machine roller speeds. Each film set contained six test films, including one unexposed intraoral film (for measuring base + fog), four exposed intraoral films, and one exposed panoramic (extraoral) film strip. To measure each autoprocessor's consistency over the 8-h day, investigators developed one test set of x-rays at time zero (defined as the point at which the developer reached operating temperature), an additional set at time zero plus 2-h and sets at 2-h increments throughout the remainder of the simulated day. A flow chart showing the processing regimen (Fig. 1) was used to help insure testing consistency.

Five hand-developed sets were processed under optimum conditions during the study. They were processed separately under exacting conditions of time, temperature, and chemistry specified by Kodak for GBX processing fluids, and their results (densities as measured on the X-Rite #301 Densitometer) were averaged. Their average density became the standard for comparison with all machine-developed films.

Investigators measured three step densities on each developed film, using the X-Rite Model 301 densitometer, taking three measurements at each of the selected steps. For the intraoral films they measured the film densities of the images cast by the 4mm, 10mm, and 16mm aluminum stepwedge thicknesses. For the extraoral (panoramic) films, they measured steps #9, #11, and #13 of the optical stepwedge. They then plotted density, minus the sum of base plus fog, against machine speed and temperature (over the 8-h test day) and compared the results to the densities of the manually processed films. The "base" is the supporting material of the film composed of polyester with a slight, bluish tint. It has a distinct, measurable density. The "fog" is film density created in the emulsion of the film by sources other than the primary beam of photons.

Density readings of radiographs developed in the machine roller speed tests during the simulated workday were then translated to film quality. In 1986 Bloxom and Manson-Hing demonstrated a clinically acceptable density range based on a comparison of stepwedge images and images of a dental phantom (9). Based on the findings of that study, DIS investigators used the range of two steps darker to two steps lighter than the optimum density as the range of acceptability. Densities falling outside that range were judged unacceptable.

RESULTS

Table 3 summarizes the physical findings for each of the evaluated processors. This two-page chart contains data for some of the conclusions at the end of this report.

Table 5 summarizes observer impressions and subjective appraisals of machine features. These features have been numerically evaluated and the autoprocessors ranked according to score.

Table 6 contains base plus fog measurements for intraoral x-rays using the aluminum stepwedge and for extraoral x-rays using the sensitometer optical stepwedge.

Tables 7 through 9 summarize the statistical analysis of the subjective portion (Phase II) of the comparison study.

Figures 2 through 7 are drawings of the processors. Each is followed by the observers' comments as they evaluated the machines.

Figures 8 through 13 contain vertical bar graphs comparing the densities of test radiographs automatically developed in the tested processors with the hand-developed control group of x rays.

DISCUSSION

Subjective rating averages (Table 5) for the Allied AP-200 and the Kodak M35A autoprocessors were above the median of 4 points. The Allied Photo Products AP-200 had the highest overall subjective rating. However, readers should evaluate based upon their specific needs. The point score of the Allied Photo Products unit does not constitute a DIS indorsement over other acceptable machines but only reflects that machine's superior rating for the specific protocol of this study.

According to the manufacturers, the two Dynaweb autoprocessors and the Peri Pro II were not to be used with currently stocklisted processing solutions (Kodak). Results of these three machines are therefore not included in this study because they were unable to meet the protocol.

The statistical analysis of the subjective portion (Phase II) of the comparison study provided the following:

- All attributes rated appear to be valid as evidenced by their reasonable spread in value range by observer (Table 7).

- The level of interobserver concordance seems to further validate the rated features (Table 8).

- All tested machines are acceptable, but the Allied Photo Products AP 200 and the Kodak M35A seem to be favorites.

- Ease of installation (feature f in Tables 4, 5, 7, 8, and 9) showed a low interobserver concordance by observers one and two, and by one and three. Observers two and three, however, agreed. This discrepancy is understandable when one sees that observer one was a medical equipment repair technician whose primary interest would likely be associated with installation and repair. The other two observers, however, were dental technicians whose interest is more likely to be in the areas of operation and daily maintenance.

The Kodak M35A was rated very highly by the evaluators, both in the quality of processed x-ray films, and in the quality of construction, but its applicability is limited because it does not accept films smaller than panoramic size. It is ideal, however, for high volume panoramic film applications.

Investigators measured warm-up times (Table 3) from room temperature to indicator light "on" or to the operating temperature recommended by the manufacturer (when no indicator light was present). The Dent-X 410 required the longest warm-up time (33 min) and the Air Techniques AT-2000 required the least (9 min).

The base plus fog densities were excessive for all intraoral films processed on short cycle times (2.5 min or less), indicating the films were not properly processed. For those radiographs processed at the tested

machines' "normal speeds," all had acceptable densities. All machines' short cycles produced readable radiographs, but the user should be aware that these cycles produced radiographs of less than optimal quality with fair to objectionable fog levels and streaking.

Thunthy reported no differences in fog production that could be detected visually between handprocessed films and those films processed in the autoprocessors he studied (3). However, the autoprocessors in the Thunthy study were not operated on short cycle times. Bloxom and Manson-Hing showed that a shift of two step densities is well within the clinical acceptability range of dentists (10). All film images of radiographs processed on the normal machine speeds were within the two-step parameter. Evaluators found, however, that short cycles of less than 2.5 min generally produced streaks and increased fog levels. The indication is that short "endo" cycles (fast roller speeds) produce decreased quality radiographs.

CONCLUSIONS AND RECOMMENDATIONS

1. Intraoral films (Kodak DF-58) processed with cycle times of 2.5 min or less were incompletely processed. Users should exercise caution when using these cycles, being fully aware that quality is the tradeoff for time saved through short processing cycles.

2. All the tested autoprocessors produced extraoral (Kodak DF-75) film image quality that is within clinically acceptable limits when processed at cycle times from 1 to 7 min.

3. There is insufficient data to be able to recommend the Dynaweb 3 and Dynaweb 10 for Air Force use because their manufacturers would not allow their use with Kodak chemicals. Film quality was acceptable when used with the manufacturers' chemicals.

4. The Allied Photo Products AP 200 and the Kodak M35A scored overall best, slightly edging the other tested processors.

5. All other autoprocessors in this study are recommended for USAF use.

6. Autoprocessor longevity cannot be predicted on the basis of this study.

7. Regardless of the point totals in Table 5, potential buyers should consider each of the recommended units on the features needed for their own clinics.

8. Further study into the clinical acceptability of intraoral radiographs processed at autoprocessor cycle times of 2.5 min or less is recommended.

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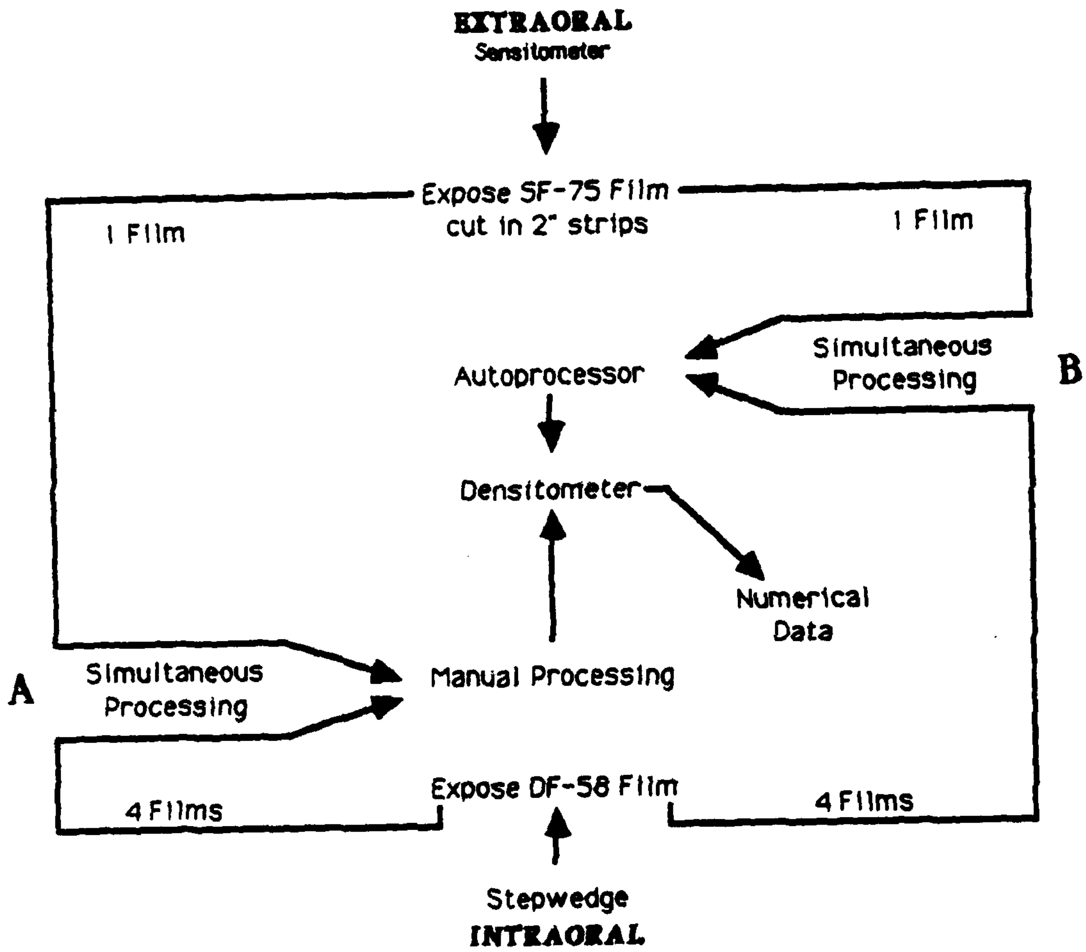

A - Process 1 sensitometer and 4 stepwedge films 5 times using manual processing at 0, 2, 4, 6, and 8 hours.

B - Process 1 sensitometer and 4 stepwedge films in each autoprocessor at warmup time plus 0, 2, 4, 6, and 8 hours.

Figure 1. Image quality flow chart.

Dental X-Ray Film Processor Study

DIS Observations*

* The following observations were taken from the actual comments made by the three independent observers as they evaluated the autoprocessors. Their subjective impressions may or may not be indicative of a machine's overall usefulness in the U.S. Air Force.

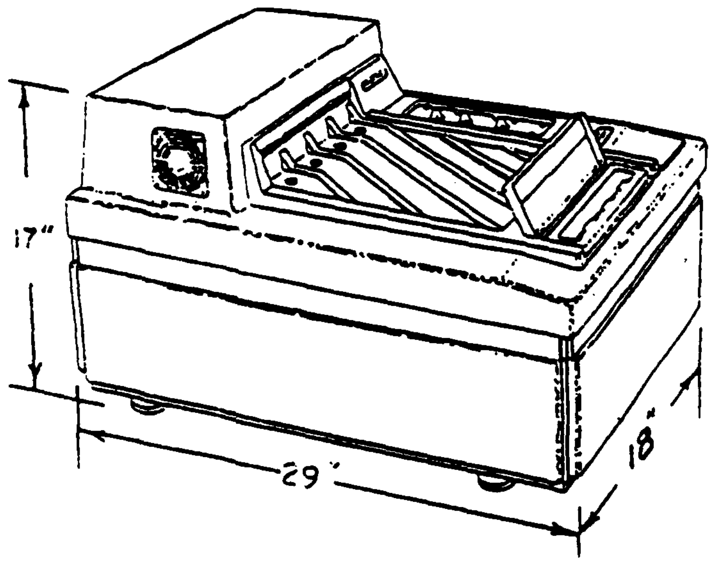

Figure 2. Allied Photo Products AP-200

a. Advantages

(1) Constructed of very sturdy materials.

(2) Maintenance and accessibility to internal components are especially good.

(3) The funnel-like covers of the tanks make solution charges easy and splashing minimal.

(4) The installation and operator's manuals are outstanding.

(5) The hinged film cover protects inserted film from light as the user leaves the dark room.

b. Disadvantages

There is no automatic standby mode.

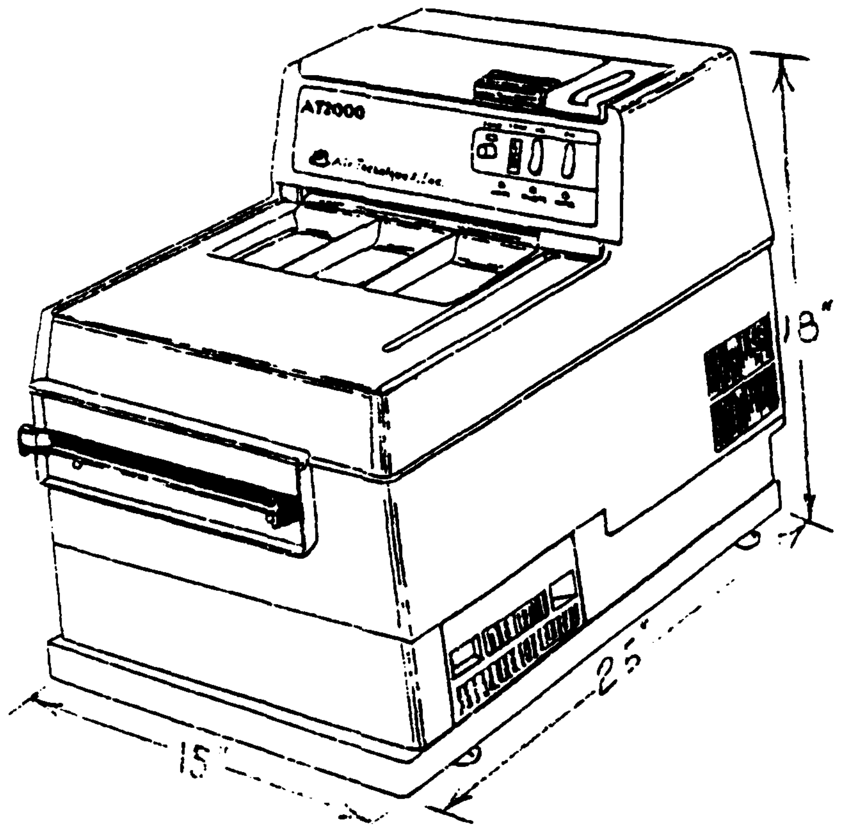

Figure 3. Air Techniques AT-2000

a. Advantages

(1) Solutions are very easily drained from the machine.

(2) Schematics of electrical controls are provided.

(3) An excellent troubleshooting manual guides the user through most common problems.

(4) The unit appears to be solidly constructed of durable materials.

(5) This is the only machine that had instructions located on the outside of the unit.

b. Disadvantages

(1) The roller assemblies seem to be put together in such a way that if a single gear breaks, the entire assembly must be replaced.

(2) The design complicates access to the machine's electronics.

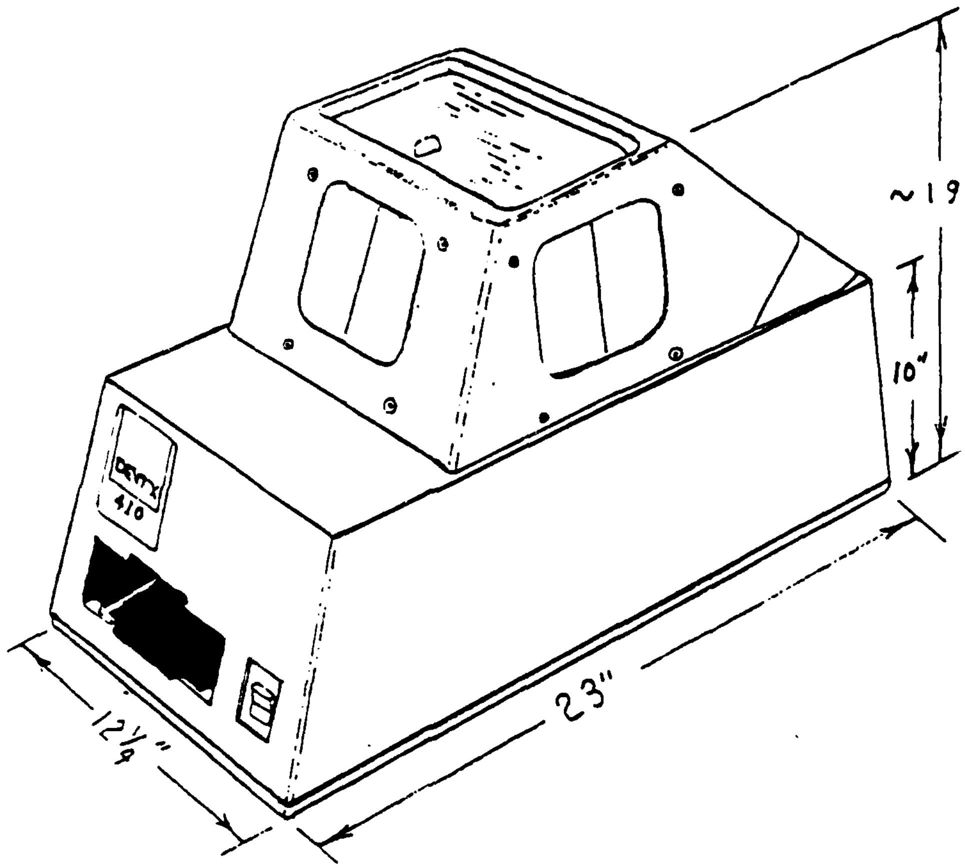

Figure 4. Dent-X 410

a. Advantages

(1) The unit is small, compact, and light weight (22 lbs).

(2) Installation is simple.

(3) Instructions and schematic inside side access panel are outstanding.

b. Disadvantages

(1) This unit is unsuitable for the volume of use required by virtually all Air Force dental clinics, due to its lack of a replenisher system.

(2) Solution tanks must be emptied by hand-dumping.

(3) Developer could be contaminated by splashed fixer as film transport roller leaves developer tank and drops into fixer tank.

(4) Solutions are heated from the side rather than from underneath the tanks, making for possible "cold spots."

(5) Warm-up time was excessive (33 min).

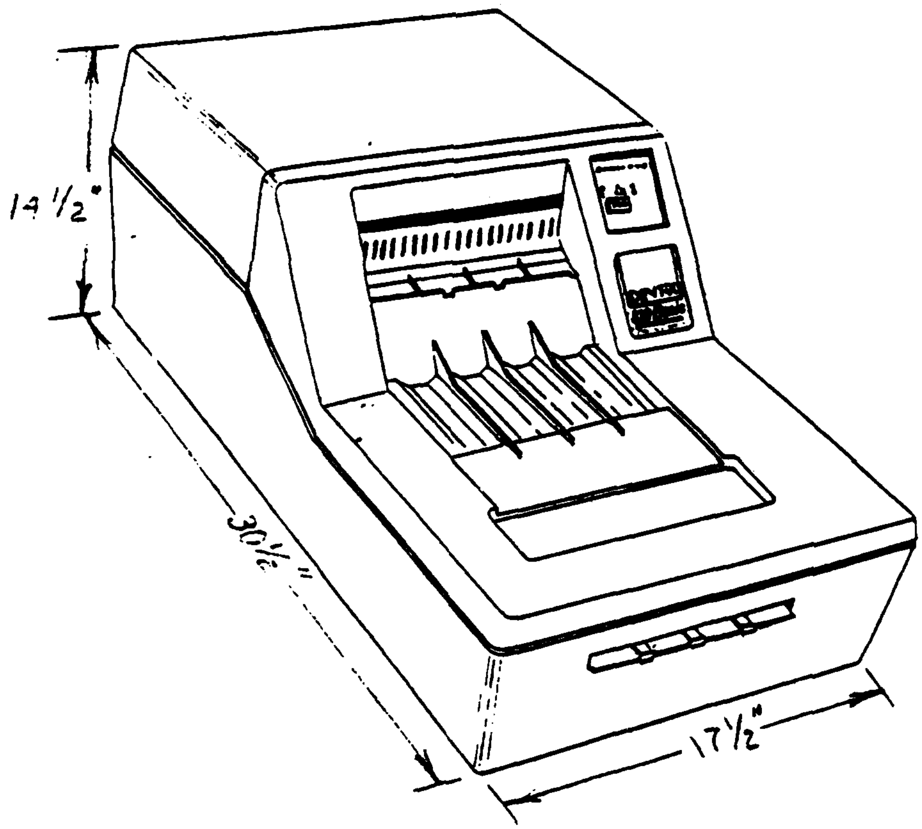

Figure 5. Dent-X 810 Basic

a. Advantages

(1) Water supply is not required if water recirculator is used.

(2) Machine has automatic standby mode.

(3) Troubleshooting guide covers film and equipment problems.

b. Disadvantages

There is no separate drain hose for the fixer tank.

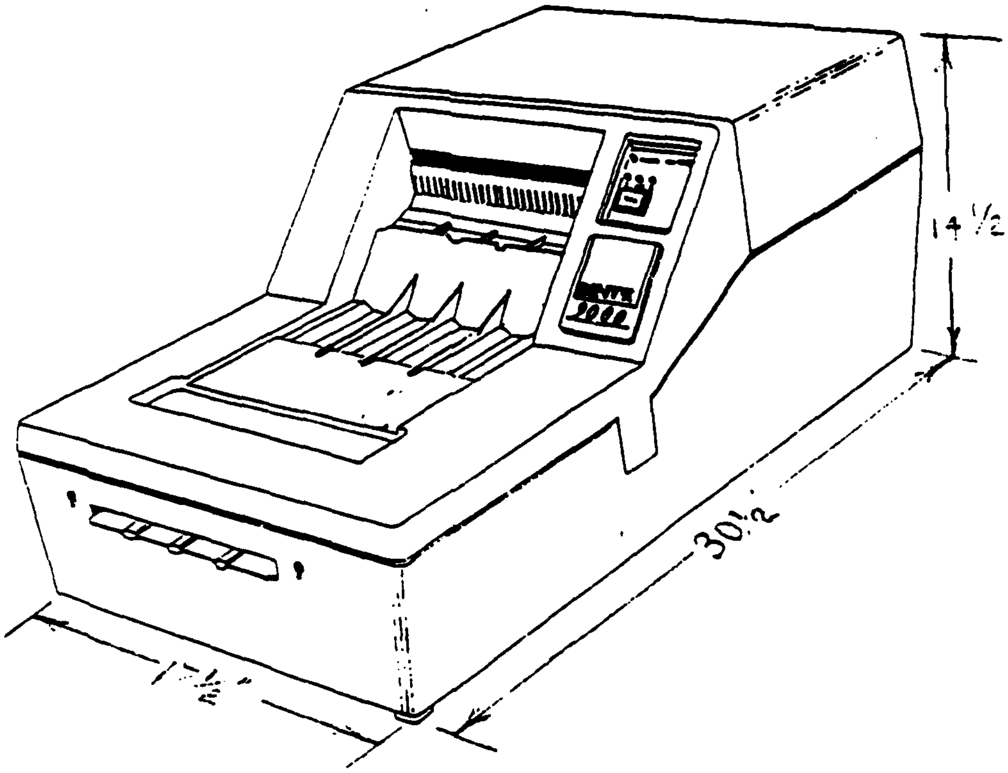

Figure 6. Dent-X 9000

a. Advantages

(1) Internal components are easily accessible.

(2) The unit is supplied with a troubleshooting guide.

(3) The automatic replenishment system makes the unit easy to operate, eliminating manual replenishment. This unit is the only one tested that has a fully automatic replenishment system.

b. Disadvantages

The main cover is difficult to position properly when it is replaced after access to internal components.

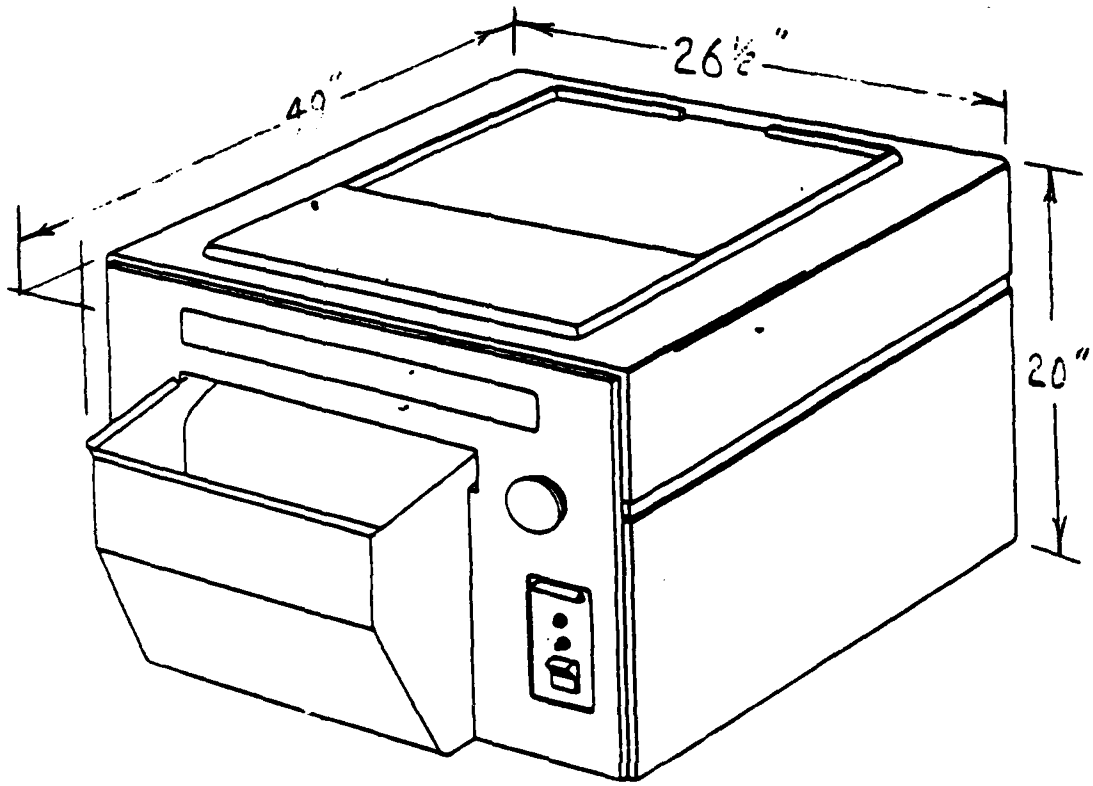

Figure 7. Kodak M35A

a. Advantages

(1) The unit appears to be easily maintained by operator and repair technician alike.

(2) The overall quality is commendable.

(3) The side panels are easily removed making accessibility to internal components excellent.

(4) Enclosed instructions and troubleshooting guide are exceptional.

b. Disadvantages

(1) This unit will not develop dental films <u>smaller</u> than panoramic.

(2) The cost of this unit may be prohibitive for smaller dental clinics.

(3) This unit should be reserved for large panoramic x-ray or cephalometric x-ray operations or other special purpose operations.

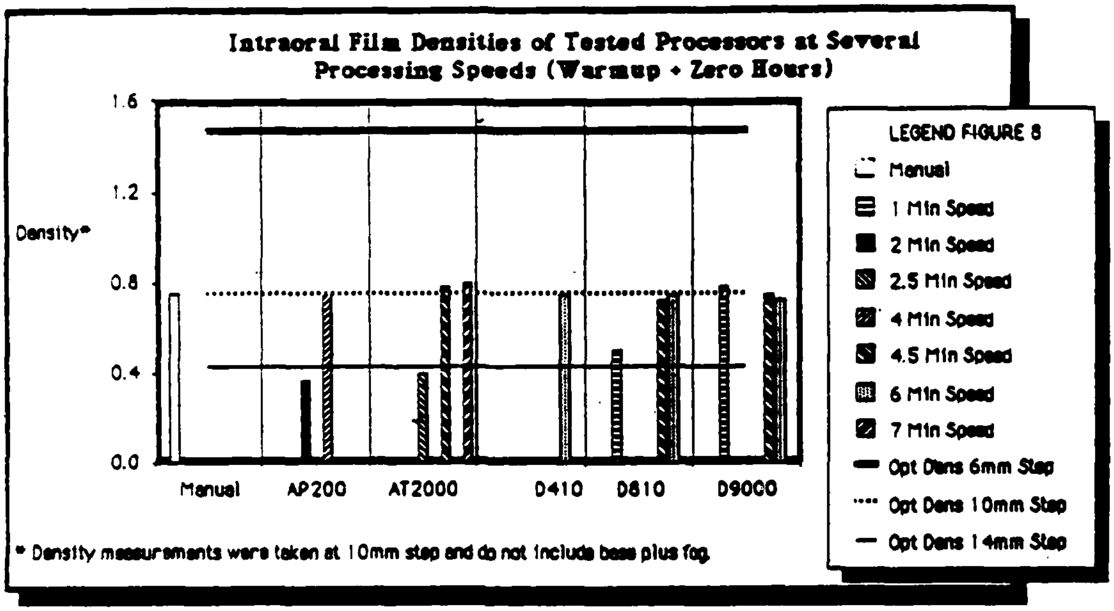

Figure 8. Intraoral film densities at several processing speeds using various processors (warmup + zero hours).

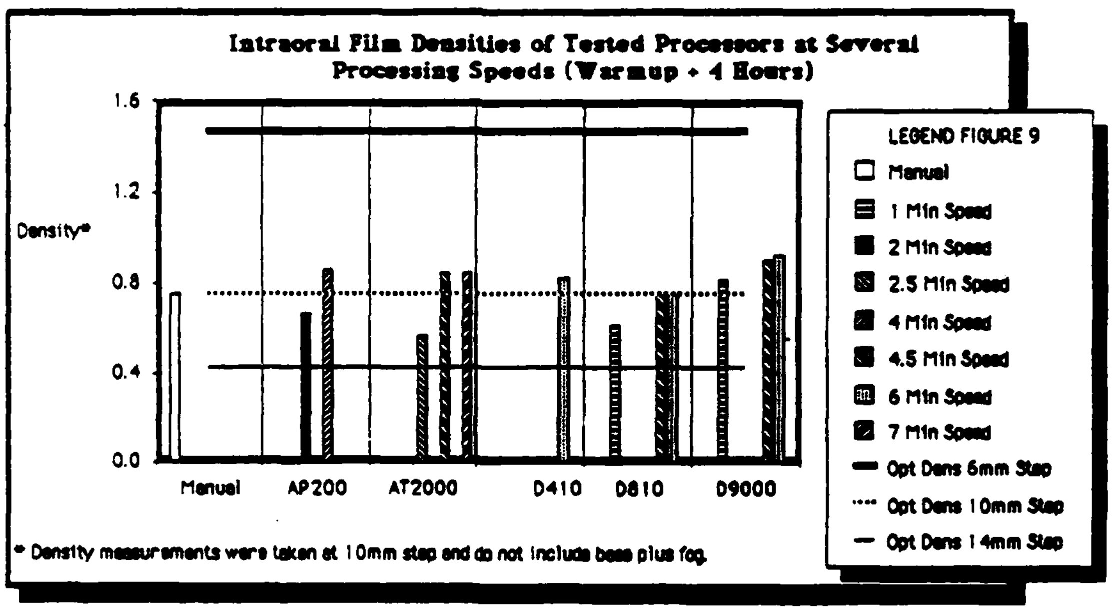

Figure 9. Intraoral film densities at several processing speeds using various processors (warmup + 4 hours).

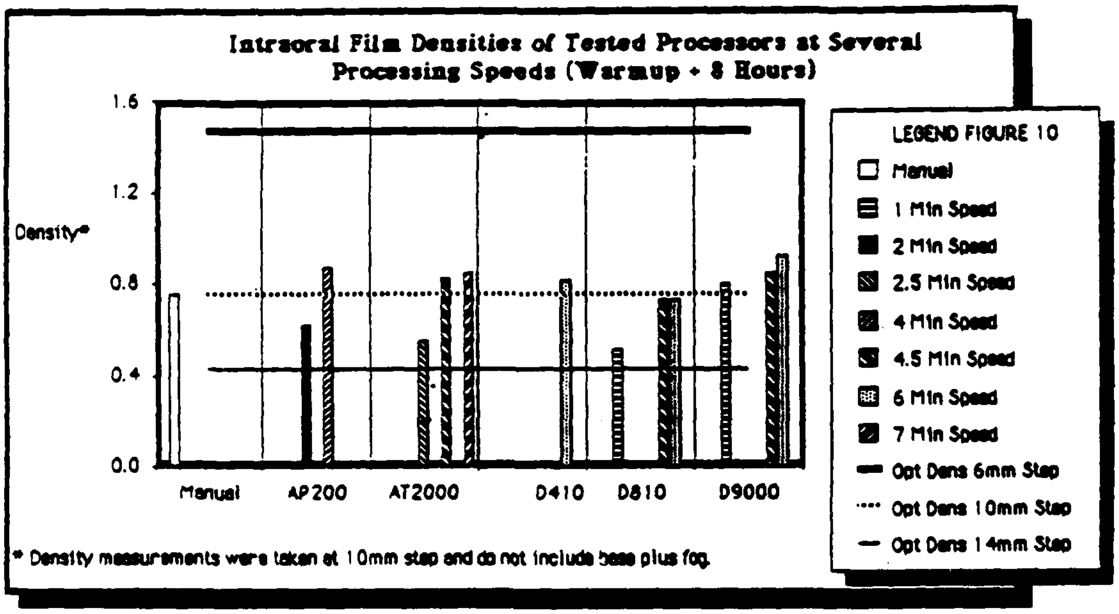

Figure 10. Intraoral film densities at several processing speeds using various processors (warmup + 8 hours).

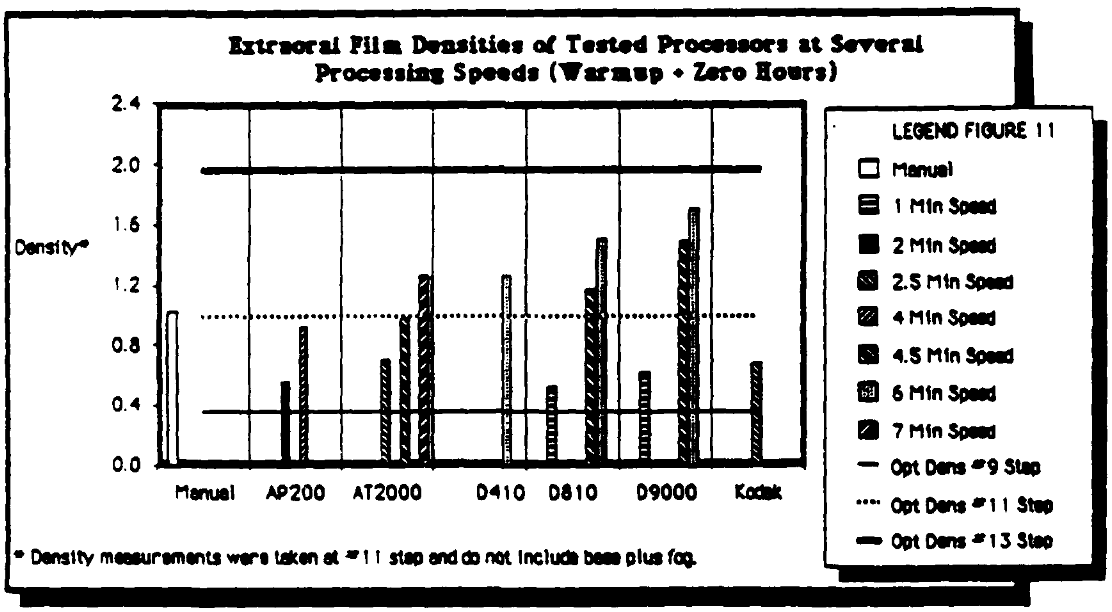

Figure 11. Extraoral film densities at several processing speeds using various processors (warmup + zero hours).

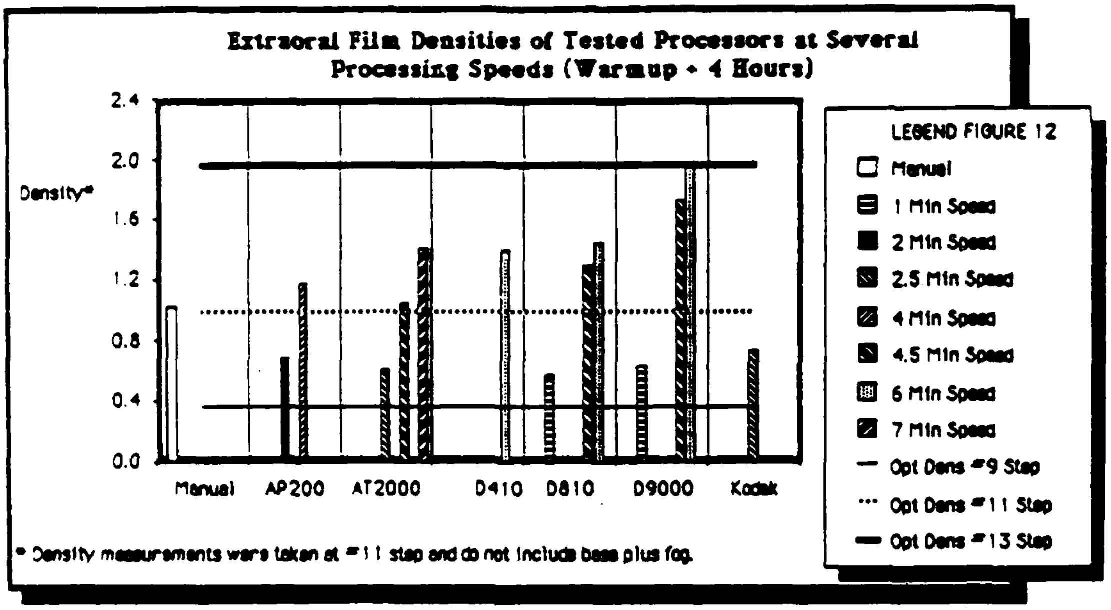

Figure 12. Extraoral film densities at several processing speeds using various processors (warmup + 4 hours).

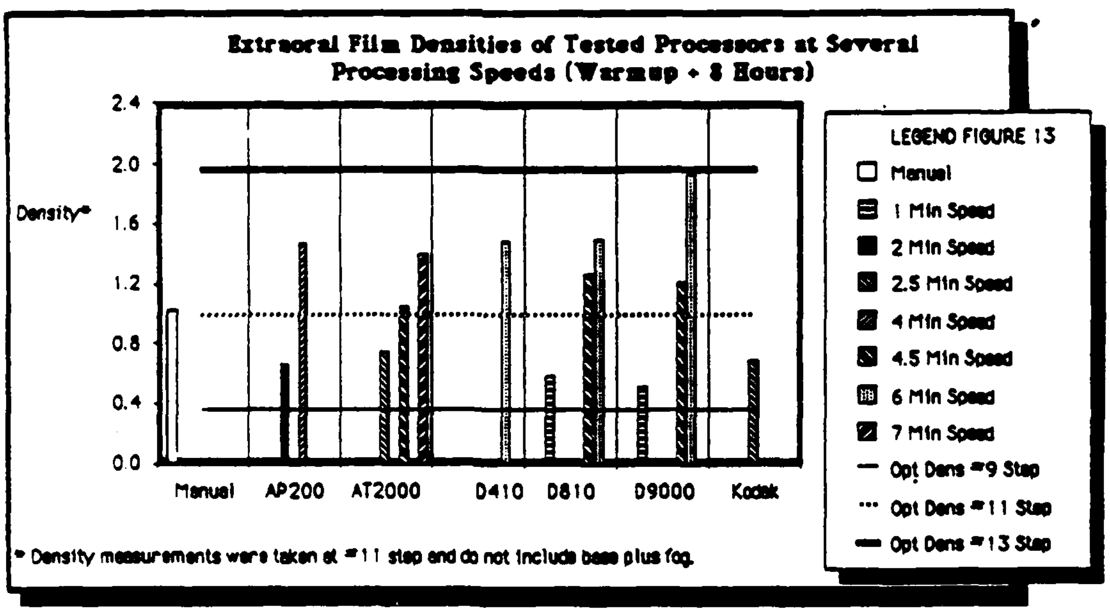

Figure 13. Extraoral film densities at several processing speeds using various processors (warmup + 8 hours).

TABLE 1. AUTOPROCESSOR STUDY - UNITS TESTED

	Manufacturer	Model Name
1.	Allied Photo Products Co	AP-200
2.	Air Techniques	* Peri Pro 2
3.	Air Techniques	AT-2000
4.	Dent-X	9000
5.	Dent-X	810 Basic
6.	Dent-X	410
7.	General Dental	* Dynaweb 3
8.	General Dental	* Dynaweb 10
9.	Kodak	M35A

* Manufacturers would not permit the use of Kodak chemistry in these models. Since these autoprocessors could not, therefore, meet the protocol of this study, results of evaluators' findings are not included here.

TABLE 2. AUTOPROCESSOR WORK SHEET

Processor:

Manufacturer:

1. Subjective Impressions	Poor				Excellent
a. Maintenance feasibility	1	2	3	4	5
b. Overall quality and durability of materials	1	2	3	4	5
c. Ease and access to internal components	1	2	3	4	5
d. Ease of maintenance	1	2	3	4	5
e. Ease of solution change	1	2	3	4	5
f. Ease of installation	1	2	3	4	5
g. Completeness of instructions	1	2	3	4	5
h. Clarity of instructions	1	2	3	4	5
i. Trouble-shooting instructions	1	2	3	4	5
j. Other comments or observations					

2. Physical Characteristics

   a. Cost
   b. Dimensions (with and without daylight loader)
   c. Film sizes accepted - list
   d. Standard accessories - list
   e. Optional accessories - list
   f. Daylight loader/yes/no
   g. Water flow rate - measure
   h. Replenishment rate - measure
   i. Processing cycle time - measure
   j. Is processing cycle time variable? yes/no
   k. Warm-up time required - measure
   l. Drain hose for fixer/yes/no
   m. Mixing valve required/yes/no
   n. Plumbing requirement - list
   o. Electrical requirement - list
   p. Grounding type - 3 plug/2 plug
   q. Cord length - measure
   r. Tank capacities - measure
   s. Weight - measure
   t. Warranty - list
   u. Maintenance required - list
   v. Recommended frequency of solution changes - list
   w. Is processing temperature variable? yes/no
   x. Recommended processing temperature - list
   y. Drying temperature - measure
   z. Miscellaneous data - list

TABLE 3. SYNOPSIS OF DENTAL X-RAY FILM PROCESSORS
(Page 1 of 2 Pages)

COMPANY NAME/ PHONE	ADDRESS	MODEL	GOVT COST #1	DAYLIGHT LOADER	GSA CONTRACT	DIMENSIONS (IN INCHES)	WEIGHT (LBS) #2
Air Techniques (516) 433-7676	70 Cantiague Rock Rd P.O. Box 870 Hicksville NY 11802	AT 2000	$2373.30	$375.30	V797P-3306h 1 Apr 87-31 Mar 90	25L x 15W x 18H	62
		Peri Pro 2 #3	$ 801.90	$ 86.40		25L x 9 3/4W x 8 1/2H	28
Allied Photo Products (404) 448-0250	5440 Oakbrook Pkwy Norcross GA 30093	AP 200	$2386.80	$417.00	V797P-3270h 1 Apr 87-31 Mar 90	29L x 18 W x 17H	58
Dent-X (800) 225-1702	250 Clearbrook Rd Elmsford NY 10523	9000	$4395.00	$460.00	None	30 1/2L x 17 1/2W x 14 1/2H	63
		810 Basic	$3495.00	"	"	30 1/2L x 17 1/2W x 14 1/2H	58
		410	$1230.00	$160.00	"	23L x 12 1/4W x 11H	23
General Dental (800) 255-0071	2630 Kaneville Ct. Geneva IL 60134	Dyna Web 10 #3	$2337.00	$297.00	None	15 3/8L x 20W x 12 1/2H	51
		Dyna Web 3 #3	$ 807.00	Included	"	15 3/8L x 11W x 12 1/2H	23
Kodak (800) 443-1529 (800) 242-2424	Health Sciences Markets Division Dept 740-B Rochester NY 14650	M35A	$4995.00	None Available	V797P-3264h 1 Mar 87-28 Feb 90	49L x 26 1/2W x 20H	200

#1 Cost includes replenisher system if available. Cost does not include daylight loader unless so stated.
#2 Dry weight, not including daylight loader.
#3 The manufacturer does not allow use of stocklisted Kodak RP X-Omat chemicals. Must purchase manufacturer's chemicals.

MODEL	ELECTRICAL REQUIREMENTS	PLUMBING REQUIRED	TANK CAP (QTS) #4	WARM-UP (MIN) #5	OPER TEMP °F	REPLENISHING SYSTEM AVAILABILITY	REPLENISHING SYSTEM METHOD	REPLENISHING SYSTEM RATE	CYCLE TIME	FILM SIZE #8	AUTO STANDBY MODE
AT 2000	115V/60 Hz	Yes #9	2.6	9	83	Optional	Push Button	185ml/ cycle	Adjustable #7	A,B,C,D E,F,G	Yes
Peri Pro 2	115V/60 Hz	No	1.0	14	78	No	#6	N/A	7 min	A,B,C,D	No
AP 200	115V/60 Hz	Yes #9	6.2	11	83	Optional	Auto	Varies: 2.5, 5, 20 or 30 min cycle	2, 4 min	A,B,C,D E,F,G	No
Dent-X 9000	110-130V/60 Hz 220V/50 Hz	Yes #9	2.6	18	83	STD	Auto/ sensor	Varies with size of film 1.5-15ml	1, 4.5, 6 min	A,B,C,D E,F,G	Yes
Dent-X 810	110-130V/60 Hz 220V/50Hz	Yes #9	2.5	13	82	No	#6	N/A	1, 4.5, 6 min	A,B,C,D E,F,G	Yes
Dent-X 410	110-130V/60 Hz 220V/50 Hz	No	2.0	33	83	No	#6	N/A	6.5 min	A,B,C,D E,F,G	No
Dyna Web 10	120V/60 Hz 220V/50 Hz 100V 50/60 Hz	Yes #9	4.0	10	82	No	#6	N/A	4.75 min	A,B,C,D E,F,G,H	No
Dyna Web 3H	120V/60 Hz 220V/50 Hz 100V 50/60 Hz	No	1.3	15	82 #10	No	#6	N/A	4.7 min	A,B,C,D E	No
Kodak M35A	120V/60 Hz	Yes #9	8.0	18	92	Optional	Auto	120ml/ min	2.5 min	F,G,H	No

#4 Developer and fixer tanks only. Does not include rinse tank(s).
#5 This is the time from "switch on" at 70 °F to "lights on" when processor solutions have reached optimum working temperatures.
#6 As there is no replenisher system, solutions must be added to this processor manually.
#7 Adjusts by 30-s increments from 1 min to 7 min.
#8 Film Sizes: A = 7/8" x 1 3/8" (size 0) B = 15/16" x 1 9/16" (size 1) C = 1 1/4" x 1 5/8" (size 2) D = 1 1/16" x 2 1/8" (size 3) E = 2 1/4" x 3" (size 4) F = 5" x 12" G = 6" x 12" H = 8" x 10"
#9 Do not attach to water softener when using Kodak chemistry. Use in-line filter in hard water areas.
#10 This developer is available without heater and temperature controller as Model 3. Runs at room temperature.

TABLE 4 SUBJECTIVE IMPRESSIONS RAW DATA

Processor	Observer	Features a	b	c	d	e	f	g	h	i
Allied Photo AP 200	Rater #1	4	4	4	4	4	3	3	3	3
	Rater #2	4	5	5	4	5	5	5	5	5
	Rater #3	5	5	5	5	5	3	5	4	5
Air Tech AT 2000	Rater #1	3	4	3	4	4	3	3	3	4
	Rater #2	4	3	4	4	5	5	3	4	5
	Rater #3	4	5	4	5	5	4	4	4	5
Dent-X 410	Rater #1	4	3	4	4	3	4	2	3	1
	Rater #2	4	2	4	4	5	5	4	4	4
	Rater #3	5	4	5	5	5	5	5	5	5
Dent-X 810	Rater #1	* Data not available								
	Rater #2	4	4	3	3	5	5	4	4	3
	Rater #3	4	3	3	3	4	3	3	3	4
Dent-X 9000	Rater #1	4	4	4	4	4	4	3	4	4
	Rater #2	4	5	4	3	4	4	4	5	4
	Rater #3	4	3	3	3	4	3	3	3	4
Kodak M35A	Rater #1	4	4	4	4	3	3	4	4	4
	Rater #2	4	4	5	4	4	3	5	5	4
	Rater #3	5	5	5	5	4	3	5	4	4

KEY TO FEATURES:

a - Maintenance feasibility
b - Overall quality and durability of materials
c - Ease of access to internal components
d - Ease of maintenance
e - Ease of solution change
f - Ease of installation
g - Completeness of instructions
h - Clarity of instructions
i - Trouble-shooting instructions

KEY TO NUMERICAL VALUES

POOR ◄——————► EXCELLENT

1 2 3 4 5

KEY TO OBSERVERS

OBSERVER #1 - Medical equipment repair technician (six years experience)
OBSERVER #2 - Dental technician (seven years experience).
OBSERVER #3 - Dental technician (sixteen years experience).

TABLE 5 SUBJECTIVE IMPRESSIONS - AVERAGES OF ALL OBSERVERS

PROCESSOR	FEATURES a	b	c	d	e	f	g	h	i	AVERAGE BY OBSERVER
Allied Photo AP 200	4.33	4.66	4.66	4.33	4.66	3.66	4.33	3.66	4.33	4.29
Air Tech AT 2000	3.66	4.00	3.66	4.33	4.66	4.00	3.33	3.66	4.66	3.99
Dent-X 410	4.33	3.00	4.33	4.33	4.33	4.66	3.66	4.00	3.33	3.99
Dent-X 810 Basic	4.00	4.00	3.66	3.33	4.00	3.66	3.33	4.00	4.00	3.77
Dent-X 9000	4.00	4.00	3.66	3.33	4.00	3.66	3.33	4.00	4.00	3.77
Kodak M35A	4.33	4.33	4.66	4.66	3.66	3.00	3.66	4.33	4.00	4.18
AVERAGE BY FEATURE	4.11	4.00	4.11	4.05	4.22	3.77	3.61	3.94	4.05	

KEY TO FEATURES:

a - Maintenance feasibility
b - Overall quality and durability of materials
c - Ease of access to internal components
d - Ease of maintenance
e - Ease of solution change
f - Ease of installation
g - Completeness of instructions
h - Clarity of instructions
i - Trouble-shooting instructions

KEY TO NUMERICAL VALUES

POOR ◄——————► EXCELLENT

1 2 3 4 5

TABLE 6

BASE PLUS FOG DATA

Processor	Cycle	Base Plus Fog: Test Object (Intraoral Film)	Base Plus Fog: Sensitometer (Panoramic Film)
Manually Developed		.15	.23
Allied Photo AP 200	4 min cycle	.15	.22
	2 min cycle	.44*	.21
Air Tech AT 2000	7 min cycle	.15	.22
	4.5 min cycle	.15	.22
	2.5 min cycle	.47*	.21
Dent-X 410	not adustable	.15	.22
Dent-X 810 Basic	6 min cycle	.15	.23
	4.5 min cycle	.15	.22
	1 min cycle	.82*	.20
Dent-X 9000	6 min cycle	.15	.25
	4.5 min cycle	.15	.23
	1 min cycle	.79*	.22
Kodak M35A	not adustable	NA	.24

* Excessive base plus fog level

TABLE 7

SUBJECTIVE IMPRESSIONS DATA RANGES BY READER AND ATTRIBUTE

	a	b	c	d	e	f	g	h	i
	Range								
Observer #1	3-4	3-4	3-4	4	3-4	3-4	2-4	3-4	1-4
Observer #2	4	2-5	3-5	3-4	4-5	3-5	3-5	4-5	3-5
Observer #3	4-5	3-5	3-5	3-5	4-5	3-5	3-5	3-5	4

KEY TO X AXIS:

a - Maintenance feasibility
b - Overall quality and durability of materials
c - Ease of access to internal components
d - Ease of maintenance
e - Ease of solution change
f - Ease of installation
g - Completeness of instructions
h - Clarity of instructions
i - Trouble-shooting instructions

KEY TO NUMERICAL VALUES

POOR ⟵⟶ EXCELLENT

1 2 3 4 5

KEY TO OBSERVERS

OBSERVER #1 - Medical equipment repair technician (six years experience)
OBSERVER #2 - Dental technician (seven years experience).
OBSERVER #3 - Dental technician (sixteen years experience).

TABLE 8 SUBJECTIVE IMPRESSIONS DATA - COEFFICIENTS OF CORRELATION

Rated Features	Interobserver Concordance: Observer #1 VS Observer #2	Observer #1 VS Observer #3	Observer #2 VS Observer #3
Feature a: Maintenance feasibility	.75	.75	.63
Feature b: Overall quality and durability of materials	.78	.60	.08
Feature c: Ease of access to internal components	.83	.60	.73
Feature d: Ease of maintenance	75	.75	1.00
Feature e: Ease of solution change	.38	.38	1.00
Feature f: Ease of installation	.23	.18	.70
Feature g: Completeness of instructions	.55	.20	.70
Feature h: Clarity of instructions	.75	-.28	-.28
Feature i: Trouble-shooting instructions	.23	.35	.38

Key to numeric values: Full Concordance 1.00 ◄—— 0 ——► -1.00 Full Non-Concordance

Key to observers:

OBSERVER #1 - Medical equipment repair technician (six years experience)
OBSERVER #2 - Dental technician (seven years experience).
OBSERVER #3 - Dental technician (sixteen years experience).

Note: The above rank correlation coefficients (Spearman r_s) were determined using the following formula.......... $r_s = 1 - \frac{6\sum D^2}{N(N^2-1)}$

Where: $D = [R(X_i) - R(Y_i)]$ $\quad \sum$ = "the sum of" $\quad$ 6 = a constant

N = # of machines evaluated. (Only 5 machines are factored here because one observer's data was unavailable on one processor.)

$R(X_i)$ = Rank value (R) by an observer (X), of each machine within a function (i).

TABLE 9 SUBJECTIVE IMPRESSIONS DATA - BEST MACHINE BY READER AND ATTRIBUTE

This chart presents the information gathered by the independent observers as they subjectively evaluated six dental x-ray autoprocessors. The observers rated each feature of each machine. Their findings were then ranked.

Machines are numbered 1-6 (see key below). Read this chart by selecting a feature and reading across to a selected observer. Example: To find how observer #2 ranked the autoprocessors with respect to "Ease of solution change", find that feature in the left-hand column. Then read across to "Observer #2". The numbers found in that spot correspond to machine rankings. ie. machines 1,2,3, and 4 were tied for best. Machines 5 and 6 tied for second best.

Rated Features	Observer #1	Observer #2	Observer #3
a. Maintenance feasibility	(1,3,5,6) ; 2	(all tie)	(1,3,6); (2,4,5)
b. Overall quality and durability of materials	(1,2,5,6); 3	(1,5); (4,6); 2; 3	(1,2,6); 3; (4,5)
c. Ease of access to internal components	(1,3,5,6); 2	(1,6); (2,3,5); 4	(1,3,6); 2; (4,5)
d. Ease of maintenance	(all tie)	(1,2,3,6); (4,5)	(1,2,3,6); (4,5)
e. Ease of solution change	(1,2,5); (3,6)	(1,2,3,4); (5,6)	(1,2,3); (4,5,6)
f. Ease of installation	(3,5); (1,2,6)	(1,2,3,4); 5; 6	3; 2; (1,4,5,6)
g. Completeness of instructions	6; (1,2,5); 3	(1,6); (3,4,5); 2	(1,3,6); 2; (4,5)
h. Clarity of instructions	(5,6); (1,2,3)	(1,5,6); (2,3,4)	3; (1,2,6); (4,5)
i. Trouble-shooting instructions	(2,5,6); 1; 3	(1,2); (5,6); 3; 4	(1,2,3); (4,5,6)

NOTE: Parenthesis indicates a rankings tie.

KEY TO MACHINE NUMBERS

1 - Allied Photo Products AP 200
2 - Air Techniques AT 2000
3 - Dent-X 410
4 - Dent-X 810
5 - Dent-X 9000
6 - Kodak M35A

KEY TO OBSERVERS

Observer #1 - Medical equipment repair technician (six years experience)
Observer #2 - Dental technician (seven years experience).
Observer #3 - Dental technician (sixteen years experience).